Valence control and f-electron magnetism of icosahedral Yb quasicrystals and approximants

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Quasicrystals possess long-range, quasi-periodic structures with diffraction symmetries forbidden to crystals. A new type of icosahedral Yb quasicrystal and approximant was discovered [1]. The Au-Al-Yb quasicrystal with Tsai-type cluster exhibits novel quantum critical behavior as observed in Yb-based heavy fermion materials with intermediate Yb valence, while the Au-Al-Yb approximant shows heavy Fermi liquid behavior [2]. Furthermore, quantum critical phenomenon of the Au-Al-Yb quasicrystal is remarkably robust against hydrostatic pressure, related to the critical state unique to the quasicrystal. By contrast, the Au-Al-Yb approximant shows heavy fermion behavior, very sensitive to hydrostatic pressure and quantum criticality of the approximant is induced by pressure [3]. Therefore, the quantum critical state of the Au-Al-Yb quasicrystal might correspond to an electronic state unique to the quasicrystals. In the process of material research [4-7], we have found superconductivity of Au-Ge-Yb approximants with Tsai-type cluster for the first time [8]. Furthermore, we have confirmed the emergence of bulk superconductivity of Al-Zn-Mg quasicrystal at a very low transition temperature of T_c = 0.05 K [9].
The icosahedral Yb quasicrystals and approximants shed a new light on strongly correlated electrons in quasicrystals. Studying the magnetism of icosahedral Yb quasicrystals and approximants by substitution and composition control of Yb ligands (Au, Al), we have found that the Au-Al-Yb system is actually located near the border of the valence change. We will discuss the variation of magnetism and mean Yb-valence by the chemical pressure effect and itinerant-electron concentration (e/a) control in the Au-Al-Yb approximant, supporting that the valence fluctuation plays a crucial role in the unconventional quantum criticality of Au-Al-Yb quasicrystal.

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